

Electronics
for
Measurement
and Control

WAYNE KERR CORPORATION

~~xxxxxx Dunc Street, Philadelphia, Pa xxxxxxxx Lomb xxxxxxx~~

22 Frink Street, Montclair, New Jersey - 746-2438

Dear Sir:

We are pleased to send you information on the products you have requested. We are certain that you will find the information useful and informative.

Wayne Kerr manufactures a quality line of Bridges which use the transformer-ratio-arm principle. In addition, Wayne Kerr also manufactures general purpose instrumentation for the measurement of distance, vibration, temperature salinity and instruments for analog analysis.

If you have any questions regarding this or any of your instrumentation problems, please do not hesitate to call us or ask to have our field representative call on you.

Very truly yours,

WAYNE KERR CORPORATION

A. DiNiro
Office Manager

AD/da

WAYNE KERR CORPORATION

22 Frink Street, Montclair, N. J. 07042 • (201) 746-2438

INNOVATIONS in INSTRUMENTATION • MEASUREMENT • ANALYSIS • SYNTHESIS • CONTROL

PRICE AND AVAILABILITY LIST

EFFECTIVE NOVEMBER 1, 1964

MODEL NUMBER		UNIT PRICE	CURRENT AVAILABILITY
AA221P	Autobalance Adapter for B221A	\$ 820.	Immediate
A321	Waveform Analyzer	900.	Immediate
A321B	Waveform Analyzer (Balanced Input)	950.	4 weeks
AT205	Air Bath Enclosure	600.	Immediate
B201	1 MC Capacitance - Resistance Bridge	1400.	3 months
B221A	Universal Bridge	980.	Immediate
B221AQ	Universal Bridge with Low Impedance Adapter, Q221	1150.	Immediate
	(Recommended external source and detector, S121 and A321 respectively)		
B521	Component Bridge	350.	Immediate
B541P	Autobalance Capacitance Bridge	680.	Immediate
B601	R. F. Bridge	800.	Immediate
B601Z	R. F. Bridge with Low Impedance Adapter, Z601	850.	Immediate
B721	Electronic Micrometer (less probes)	760.	Immediate
B721Q	Electronic Micrometer complete with Q721	960.	Immediate
B731A	Vibration Meter (Less probes)	1130.	Immediate
B731AQ	Vibration Meter complete with Q731	1450.	Immediate
B801B	1-100 MC, 3 terminal Admittance Bridge	1150.	Immediate
	(Recommended Source & Detector, S161 and R161 respectively)		
B901	V. H. F. Admittance Bridge	940.	Immediate
	(Recommended Source & Detector, S261 and R261 Respectively)		
C121	Conductivity Sampling Cell	100.	Immediate
C221	Conductivity Flow Cell	100.	Immediate
C321	Conductivity Loop or Immersion Cell	250.	Immediate
C421	Conductivity Needle Probe	100.	Immediate
C521	Platinum Electrode Conductivity Cell	130.	Immediate
D121	Dielectric Sampling Cell	100.	Immediate
D221	Dielectric Flow Cell	100.	Immediate
D321	Dielectric Micrometer Jig	400.	Immediate
DM100	Distance Meter (less probes)	900.	Immediate
DM100Q	Distance Meter complete with Probe Holder and probes	1220.	Immediate
F731	Filter for Low Amplitude Vibration	90.	Immediate
JB731	Probe Selector Switch, 6 way, for use with B721, B731A and DM100	350.	Immediate
MB100	Humidity Midge (Miniature Bridge)	250.	Immediate
	Probe HPE-1 with lead HPL-1	80.	Immediate
MB200	Conductivity Midge (Miniature Bridge)	250.	Immediate
	Cell C522 with lead CPL-1	120.	Immediate
	Micro Sampling Cell C524 with lead CPL-2	120.	Immediate
MB300	Temperature Midge (complete)	250.	Immediate
	Leather Carrying Case for Midge Series	20.	Immediate

(over)



Q22D	Video Oscillator (75Ω output).....	780.	Immediate
Q22DA	Video Oscillator (50Ω output).....	780.	Immediate
PS109	Power Supply for AA221/B541.....	70.	Immediate
PC1	Probe Holder for B721 or B731A.....	80.	Immediate
PC3	Right Angled Probe Holder.....	90.	4 weeks
PC5	Triaxial Probe Holder.....	100.	Immediate
Probes A1, B1, C1, D1, E1, F1, G1, for B721 and B731A.....		70.	Immediate
Probes WKA400, WKB400, WKC400, WKD400, WKE400, WKF400, WKG400			
	400°F operation including cable.....	185.	4 weeks
Probes WKA1000, WKB1000, WKC1000, WKD1000, WKE1000, WKF1000, WKG1000			
	1000°F operation including cable.....	600.	4 weeks
Q221	Low Impedance Adaptor for B221.....	190.	Immediate
Q251	Wide Band R. F. attenuator (75Ω).....	105.	Immediate
Q251A	Wide Band R. F. Attenuator (50Ω).....	105.	Immediate
Q561	Bridge Standards for B901.....	260.	4 weeks
Q601	D. C. Control Unit for Transistor Adaptors for B601 bridge.....	120.	Immediate
Q601 (A-E)	Set of Five Transistor Adaptors for B601(\$80 each) PNP.....	400.	Immediate
Q601 (V-Z)	Set of Five Transistor Adaptors for B601(\$80 each) NPN.....	400.	Immediate
Q721	Set of 2 probes, probe-holder, in case (B721).....	230.	Immediate
Q731	Set of 4 probes, probe-holder, in case (for B731A).....	370.	Immediate
Q761	Bridge Standards for B801.....	260.	Immediate
Q801A	Transistor Adaptor for B801 bridge.....	700.	4 weeks
R161	Detector for use with B801.....	500.	Immediate
R261	Detector for use with B901.....	500.	Immediate
RA-141	Resistance Adaptor for M141.....	325.	Immediate
S121	Audio Signal Generator.....	470.	Immediate
S121T	Audio Signal Generator (Balanced Output).....	510.	4 weeks
S161	Source for use with B801.....	450.	Immediate
S261	Source for use with B901.....	450.	Immediate
SA100	Transfer Function Computer.....	8400.	6 weeks
SA200	Root Solver.....	2000.	6 weeks
SA400	Modulator/Demodulator for use with SA100.....	1000.	6 weeks
SA500	Filter for SA100.....	1000.	6 weeks
SA600	Transfer Function Synthesizer.....	2000.	6 weeks
T121	Wide Band Balanced Transformer for use with S121.....	40.	Immediate
TA221	Transistor Adaptor for B221A.....	560.	Immediate
Z601	Low Impedance Adaptor for use with B601.....	60.	Immediate
	Instrument Carrying Cases.....	15.	Immediate
	Additional Instruction Manual.....	5.	Immediate

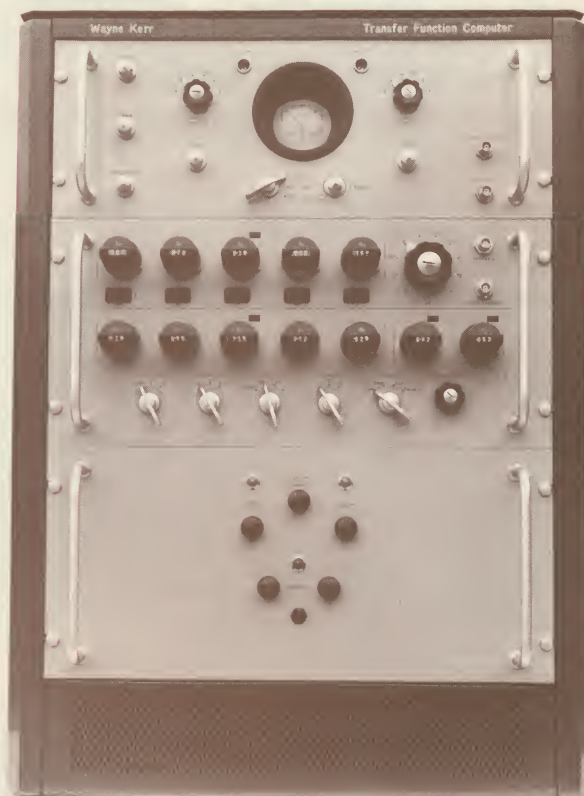
Rack Mounting — any instrument (add suffix "R" to Model No.) add \$30 and 2 weeks
Minimum Billing..... \$5.00

All prices and deliveries subject to confirmation by quotation.

WAYNE KERR



TRANSFER FUNCTION COMPUTER MODEL SA-100



- Rapid, Accurate, Direct Measurement of the Transfer Function of four-terminal networks, components, systems.
- Direct Readout of Transfer Function, with up to 4th-order numerator, 6th-order denominator.
- Performs Dynamic Measurements on servo and control systems, active and passive networks, and system analogs.
- Simple Visual Null-Balance on CRT display — no calculations, plots, or tables required.
- Selectable System Excitation: sinusoidal, step-function, ramp, or parabolic waveform.
- Variable Excitation Frequency: from 0.015 to 400 cps.
- High Coefficient Accuracies: typically from $\pm 1\%$ to $\pm 5\%$ depending upon order of term.
- Non-Linear Systems effectively analyzed.

INNOVATIONS *in* INSTRUMENTATION

TRANSFER FUNCTION COMPUTER

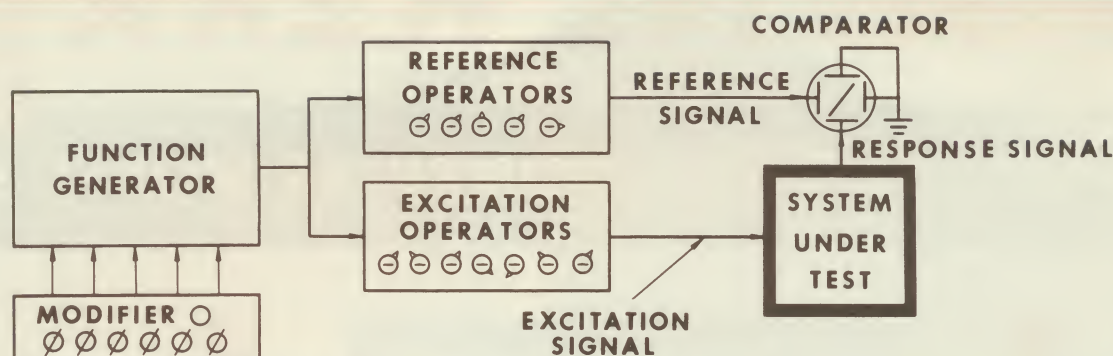


Figure 1. TFC Simplified Block Diagram

FEATURES

The Wayne Kerr Model SA-100 Transfer Function Computer enables the operator to measure (or synthesize) the Transfer Function of any electrical device, from the most sophisticated closed-loop electromechanical servo system to the simplest of four-terminal networks or control components. The measurement is performed directly upon the system itself, and the transfer function is displayed on the front panel of the Computer as an equation with a 4th-order numerator and a 6th-order denominator, with the latter factored into a quadratic and a quartic for added convenience. The coefficient for each term is registered as a digitally-displayed numeral on the control dial for that term. The analysis of the system under test is accomplished by electronic means, as the operator manipulates the controls of the TFC, without the need for transient-response data, sine-wave amplitude-phase response data, Fourier analysis, analytical calculation, Nyquist-Bode plots, or any of the other tedious operations normally encountered in the mathematical calculation of the system transfer function. The measurement may be made using sinusoidal, parabolic, ramp, or step-function excitation, determined by a selector switch on the front panel. The sinusoidal frequency range is 0.015 to 400 cps.

As indicated in the simplified block diagram of Figure 1, the TFC generates the selected waveform, applies it (after operating upon it in a known manner) to the system under test, and compares the system response signal with an internally-generated reference signal, obtained by operating (in a known manner) upon the same selected waveform. When the reference signal is adjusted, by means of front panel controls, so that it matches the system response signal (observing both displayed as a Lissajous pattern on the comparison oscilloscope on the instrument panel), then the equation on the panel represents the transfer function of the system, and the control settings indicate the coefficients of each term of the equation, as seen in Figure 2.

The simplicity and speed with which the measurement is accomplished are not achieved at the expense of accuracy or understanding of the physical system. Used on linear systems of up to the fourth order, the first and second order coefficients obtained will have an uncertainty of approximately $\pm 1\%$ of the actual value (or $\pm 0.2\%$ of the maximum value, whichever is greater); uncertainty in the third and fourth order coefficients will be approximately $\pm 5\%$ of the actual value (or $\pm 1\%$ of the maximum), and the quadratic factor will have an uncertainty of approximately $\pm 2\%$ (of actual), or $\pm 0.2\%$ (of maximum). When desired, the TFC cathode ray tube can display directly the transient response of the system to a discontinuous function, and can also rapidly and conveniently provide a phase-gain plot at a selection of frequencies within the 0.015 to 400 cps range.

As Figure 1 indicates, there are potentially three independent sets of variables involved in performing a measurement with the Transfer Function Computer: the Excitation Signal, the Reference Signal, and the System under test. This points up a unique capability of the TFC:

Conventional, quantitative analysis of the performance of a four-terminal network or control system (before the introduction of the TFC) involved a painstaking accumulation of test data, either as transient-response waveforms, or as sine-wave gain-phase response characteristics, followed by a tedious mathematical analysis, aimed at deriving the transfer function of the system. Needless to say, this process presupposes the existence of a fixed network or system; any attempt to alter the device under test invalidates the previously-gathered data, and requires a repetition of part (or all) of the effort.

The fast, simple procedure for transfer-function measurement afforded by the TFC makes it practical to vary the system under test and rapidly determine the results of such variation. Thus the development engineer can select the Excitation signal, inspect the system Res-

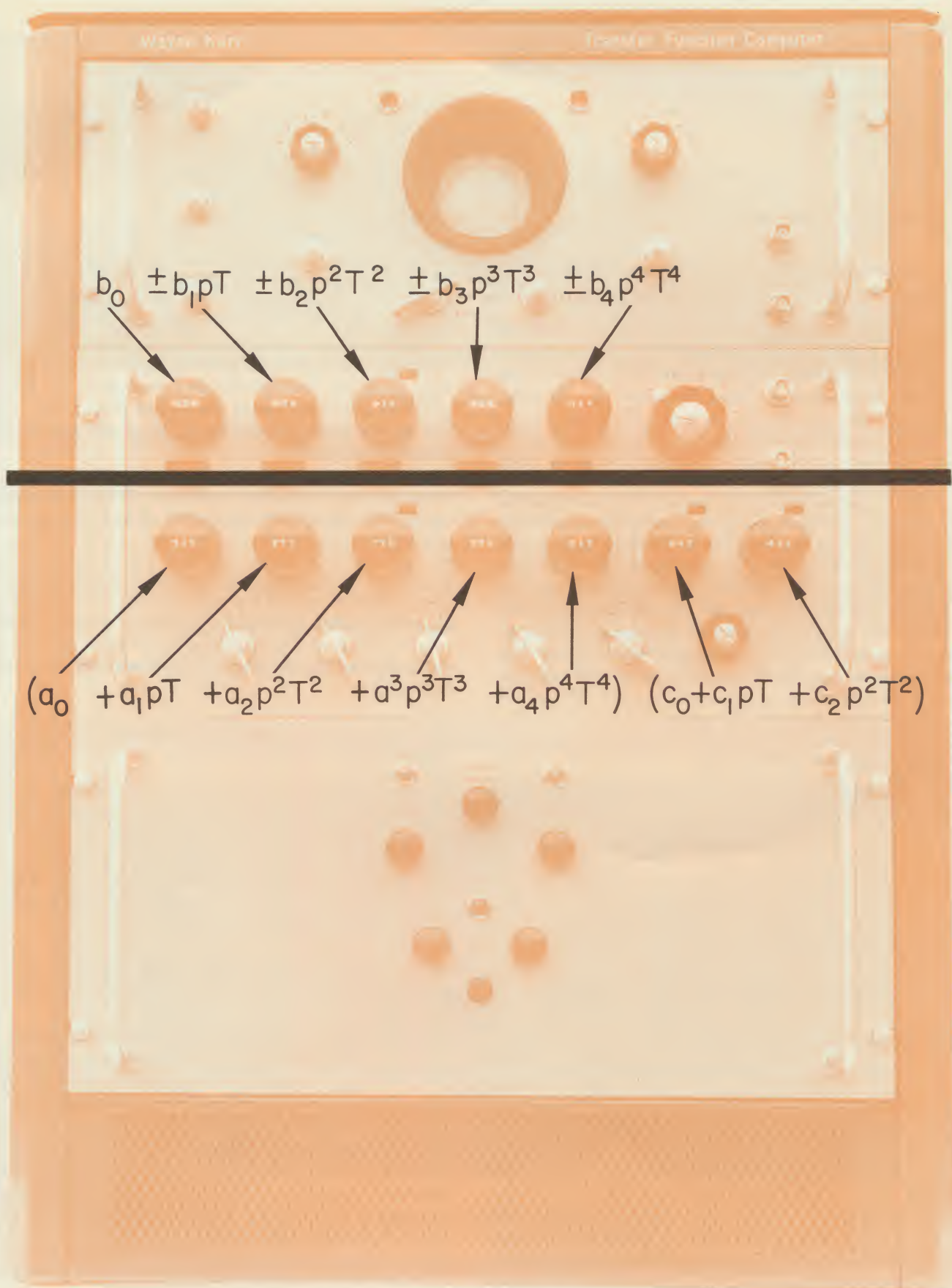


Figure 2. System Transfer Function

ponse, then determine the effect of varying a system component or parameter simply by manipulation of convenient panel controls — controls which may just as rapidly be returned to the original condition corresponding to the system behavior prior to the experiment. Alternatively, he can select the desired Excitation, establish the desired Response, then adjust the system so as to achieve this Response. It is also possible to determine the Excitation required to produce a given Response with a given system.

The operating controls of the instrument are logically arranged and clearly identified to facilitate deriving the complete transfer function in a minimum number of steps, without burdening the operator with the need for a running analysis of the internal functions of the instrument to achieve a valid measurement. Of the three panel-mounted sections that comprise the Transfer Function Computer, the top section (the Monitor Unit, Figure 3) houses the CRT display, with the gain, shift, and focusing controls used to adjust the display trace for optimum observation of the presented waveforms; the center section (the Computer Unit, Figure 4) houses the circuitry for generating the Excitation and Reference signals, and the controls for determining the type and frequency of excitation, as well as the numerical values and polarities of the equation coefficients for the measured function. The bottom section houses the DC and AC power supplies that furnish operating potentials to the circuits in the upper two sections. The instrument is completely self-contained, and operates from a 50 to 60 cycle AC power line, at 107, 205, or 235 volts (nominal), drawing 750 watts.

PRINCIPLES OF OPERATION

The relationship between the input (Excitation) and the output (Response) of any four-terminal system is always of the form:

$$B_0 E + B_1 \frac{dE}{dt} + B_2 \frac{d^2 E}{dt^2} \dots + B_m \frac{d^m E}{dt^m} =$$

$$A_0 R + A_1 \frac{dR}{dt} + A_2 \frac{d^2 R}{dt^2} \dots + A_n \frac{d^n R}{dt^n}$$

where E = excitation and R = response.

The corresponding transfer function is

$$F(p) = \frac{B_0 + B_1 p + B_2 p^2 \dots + B_m p^m}{A_0 + A_1 p + A_2 p^2 \dots + A_n p^n}$$

If the coefficients $A_0, A_1, A_2 \dots A_n, B_0, B_1, B_2, \dots B_m$ of the differential equation of the system can be measured, the complete transfer function is immediately known. (Any non-existent terms will, of course, have zero coefficients.) Given the transfer function, the roots of the denominator may be extracted, and the complete behavior of the system can be related directly to its physical parameters. The Model SA-100 Transfer

Function Computer offers a direct means of measuring the A and B coefficients, and hence of establishing the transfer function in numerical form.

In practice, the measurement process is performed by an adjustment sequence on the panel controls of the Computer Unit (refer to Figure 4). The signal produced by the internal function generator is modified by means of the bottom row of controls, and the ωT switch, to establish the characteristics of the basic energizing signal. This may be a sinusoidal, triangular or parabolic waveform, or manually controlled step, as selected by the setting of the FUNCTION switch. The sinusoidal frequency is determined by the setting of the two T switches (.001sec — 4secs) and the 10-position ωT switch which, together, cover the range 0.015 cps — 400 cps. The repetition frequencies of the triangular and parabolic waveforms are controlled by the T switches alone and cover the ranges 0.0125 cps — 50 cps for the triangular and 0.125 cps — 100 cps for the parabolic function.

A square-wave excitation would be obtained by registering the appropriate derivative of the triangular or parabolic function.

Magnitude of the signal is controlled during measurement by EXCITATION LEVEL but will also be affected by SCALING switch and denominator coefficients.

D. C. Bias of the excitation can be effected by 'D. C. CONTROL'.

The signal thus determined is fed to two "operational manipulation" channels, which perform successive differentiations upon the signal, summing the individual derivations, whose outputs are controlled by the twelve potentiometers on the panel. These potentiometers pick off widely-adjustable fractions of discrete derivatives of the signal. The circuit parameters are chosen so that the magnitude of each fraction bears a direct relationship to the coefficient of one of the terms of the transfer function

$$F(p) = \frac{b_0 \pm b_1 p \pm b_2 p^2 \pm b_3 p^3 \pm b_4 p^4}{(a_0 + a_1 p + a_2 p^2 + a_3 p^3 + a_4 p^4) (c_0 + c_1 p + c_2 p^2)}$$

The equation is arranged on the panel as indicated in Figure 2. The seven* lower potentiometers control the a and c coefficients in the denominator, while the five upper potentiometers control the b coefficients in the numerator. A switch beneath each of the numerator potentiometers permits selecting positive or negative polarity for each of the five numerator terms. In the numerator channel, a summing amplifier combines the individual potentiometer outputs, and presents a composite Reference signal which is delivered to the horizontal channel of the comparison oscilloscope in the Monitor Unit. A similar summing amplifier in the de-

* c_0 has a fixed value of unity, hence requires no potentiometer.



Figure 3. Monitor Unit

nominator channel combines the seven potentiometer outputs, delivering a composite excitation signal which is applied to the input of the System under test. The output signal of the System is applied to the vertical channel of the comparison oscilloscope.

If the denominator represents the System Response, and the numerator is adjusted so that it represents the System Excitation, then the complete ex-

pression will represent the transfer function of the System. The measurement process therefore consists essentially of sequential adjustments of the coefficient potentiometers to achieve a match between the Reference and System Response signals, observing the effect of each adjustment on the waveform displayed in the comparison CRT as a Lissajous pattern. The display will alter progressively from an ellipse to a straight line, as the adjustments converge on equality of the

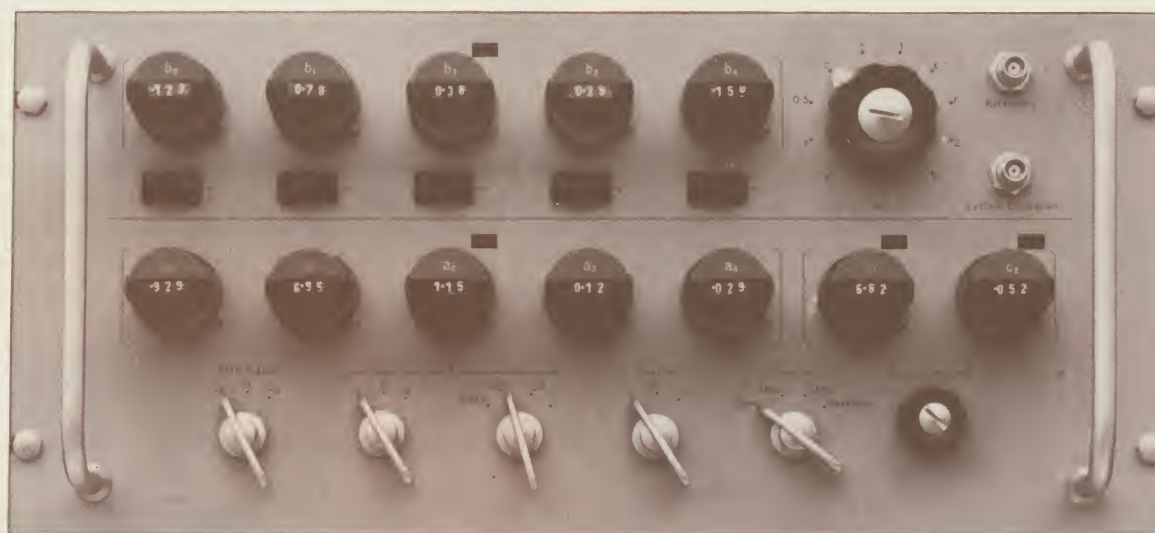


Figure 4. Computer Unit

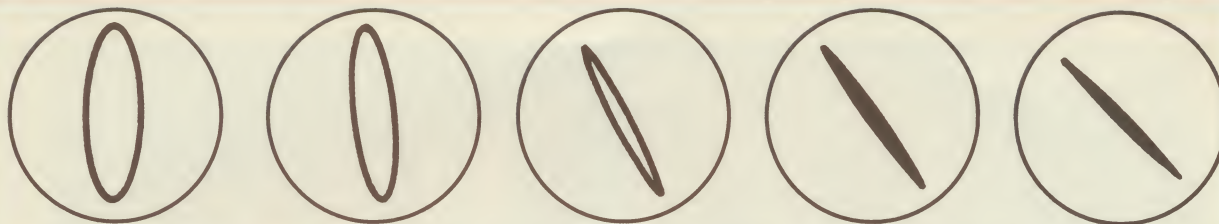


Figure 5. Adjustment of Scope Pattern for Reference/Response Equality.

two signals, as indicated in Figure 5. Equality (a perfect "match") is indicated by a straight-line trace at an angle of 45° with the horizontal; since it is impracticable to gauge the angle exactly by eye, the Display Selector switch on the Monitor Unit is then set to NULL position, changing the CRT display to a straight vertical line, and final trimming adjustments of the coefficient potentiometers are performed to reduce this line to a spot, indicating true equality, within the limits of accuracy previously stated. The digital settings of the potentiometers then provide the values of the coefficients of the transfer function of the system, without the necessity of calculation of any kind.

The simplicity of this procedure obviously makes it practical, at this point, for the operator to make a substitution or variation in the System under test, observe the effect on the CRT display, then adjust the coefficients to again produce an equality, in this way quickly and definitively determining the influence of individual System parameters on the transfer function.

APPLICATIONS

The Model SA-100 Transfer Function Computer is readily employed in a variety of fields, for analyses or tests of systems and components. It provides the means for direct analysis of servo and control systems, guidance and navigation systems, analog computation and data processing equipment, active and passive networks and components. It facilitates analysis of mechanical, thermal, hydraulic, and aerodynamic systems and structures by analysis of electrical analog models of these projects, and can be applied in a similar manner to the solution of mathematical problems by analog technique.

Because of its unique ability to operate "in reverse", the TFC opens the way to rapid, accurate, dynamic synthesis of these systems, components, and structures, with a radical reduction in the time and expense ordinarily inherent in such investigations.

A less-apparent but equally important application of the Model SA-100 is the production-line test and acceptance of systems and their components. By pre-setting the instrument to the requisite characteristics of the product, the performance of each unit may be

checked against the specifications, and in many cases can be adjusted on the spot to match the performance specifications. Since the test is performed using a visual display for comparison, the need for highly-skilled test personnel may be eliminated or greatly reduced, and the test station can become an integral part of the production line.

USEFUL ACCESSORIES

Supplementing the Model SA-100 Transfer Function Computer, and further extending and simplifying the process of System analysis and synthesis, the instruments described below offer additional degrees of freedom to the systems engineer, both in the scope of his investigations, and in the speed and efficiency with which they may be accomplished.

The Model SA-200 Root Solver.

Like the TFC, the Root Solver applies electronic analog techniques to the solution of mathematical relationships, enabling the operator to derive quick answers by manipulation of simple controls in conjunction with a visual display, rather than by a prolonged and tedious calculation. Designed originally to expedite the analytical processes undertaken by the TFC, the Root Solver is a compact, transportable, solid-state instrument (Figure 6) that may be used independently, in a wide range of scientific and engineering activities, for the solution of higher-order polynomial equations. Both the real and imaginary roots of equations up to the sixth order can be extracted in a matter of minutes, and the plotting of root loci for varying values of a system parameter is enormously simplified.

The Model SA-200 is designed to solve equations of the form

$$f(p) = \pm A_0 + A_1p \pm A_2p^2 \dots \pm A_6p^6$$

in which A is a constant having either positive or negative sign, and p is the complex variable. The roots of the right-hand side of the equation are those values of p that makes f(p) equal to zero. The instrument operates by applying a 1000-cps sinusoidal signal to a circuit whose transfer function is defined by the right-hand side of the equation above.

Seven potentiometers on the panel permit setting in the values of the coefficients A_0 to A_6 of the equation to an accuracy of 2%, and a $\pm$ switch beneath each potentiometer permits selecting the sign of each term. The real and imaginary components of p are varied by two multi-gang potentiometers, enabling a search of the complex plane by quadrants, in conjunction with the sign-reversing switches. The output of the system is resolved into in-phase and quadrature components by two phase-sensitive detectors, whose outputs drive individual center-zero meters on the panel. As a root is approached, these outputs will approach zero; accordingly, the root potentiometers are adjusted so as to zero the meters, at which point the real and imaginary components of the root can be read off the calibrated dials associated with the root potentiometers. High sensitivity in the null region is ensured by a final tuned amplifier stage with a gain of 500, and by the noise-rejection property of the phase-sensitive detectors. The magnitudes of the in-phase and quadrature components of any remainder are indicated on the panel meters; a facility is also provided to use one of the meters to indicate the remainder as a modulus, selectable by a toggle switch on the panel.

The Model SA-200 is designed for bench-top mounting (8" high, 18" wide, 10" deep), (20 x 46 x 25 cm) weighs 30 pounds (13.5 kg), and operates from a 110 or 200-250V power line, drawing 10 watts.

The Model SA-400 Modulator-Demodulator

This accessory to the Model SA-200 Transfer Function Computer extends its application to carrier systems. A front panel control provides for carrier frequency operation at 50, 60, 400, 1600, and 2400 cps. The Modulator section mixes the carrier signal with the output signal of the TFC, providing a low-distortion, wide-range System Excitation signal consisting of the selected carrier with the TFC signal as a modulation envelope.

A linear, balanced demodulator detects the modulated System Response signal, suppressing the carrier. An "equalizer" circuit, having a transfer function exactly equal to that of the product of the Modulator and Demodulator sections, when connected in the Reference lead of the TFC cancels their effect; so the measurement represents only the transfer function of the System under test.

The Model SA-400 is designed for panel mounting (19" wide, 8 3/4" high, 7" deep) (48 x 22 x 18 cm), weighs 28 pounds (12.8 kg) with case, and may be operated from 100-125 V or 200-250 V, 40-60 cps line power, at consumption of 5 watts.

The Model SA-500 Variable Filter

When it is necessary to conduct System measurements with the TFC at very low signal-to-noise ratios, the Model SA-500 Variable Filter may be employed to reject all undesired frequency components, materially improving the operator's ability to achieve true balance on the CRT display.

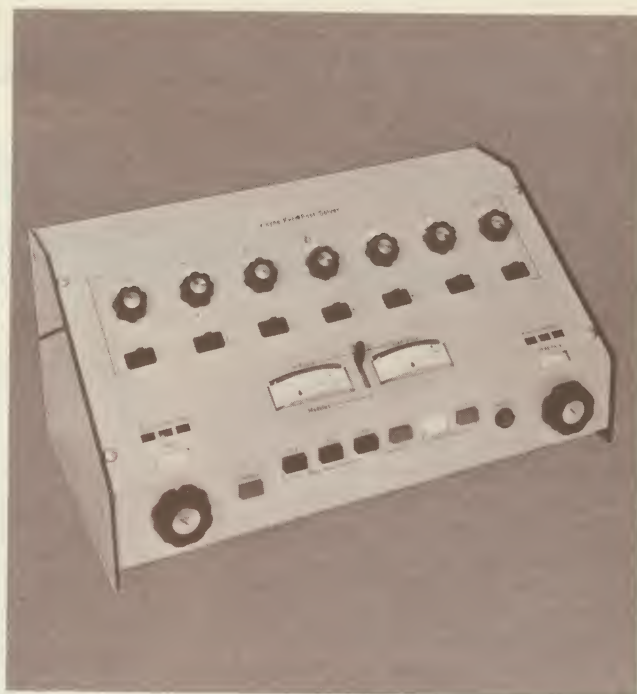


Figure 6. Model SA-200 Root Solver

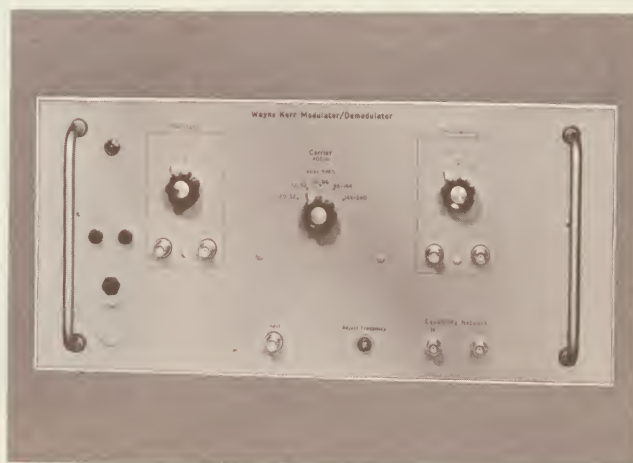


Figure 7. Model SA-400 Modulator-Demodulator



Figure 8. Model SA-500 Variable Filter

The Unit consists of two identical 3-section maximally flat low-pass filters which are switched to provide either balanced (twin) low pass filters tunable from 0.159 cps to 1592 cps (18 db/octave) or a single sharp cut-off filter (36 db/octave) over the same frequency range. Switched rearrangement of the filters makes available one band-pass filter have 18 db/octave sides. Used as a single filter, low-pass or band pass, it would be connected between the linked sockets at the rear of the Monitor unit when the Monitor is switched to 'NULL'. The frequency of band-pass would be adjusted during measurement to produce exactly zero phase-shift at the particular excitation frequency.

When operating the TFC in the "45°" display mode, the Model SA-500 is used as a twin low-pass device, with one section connected in series with the System Excitation signal, and the other section in series with the System Response Signal. The two sections being essentially identical, their presence has no effect on the validity of the measurement, and greatly improves the useable discrimination and sensitivity.

The Model SA-500 is mounted in a portable case, or 19" rack. (9" high, 20" wide, 9" deep) (23 cm x 51 cm x 23 cm), and weighs 23 pounds (10.3 kg).

The Model SA-600 Transfer Function Synthesizer (Figure 9).

An outgrowth of the TFC principle, the Model SA-600 is an extremely versatile and useful device. As its name implies, it will synthesize any transfer function



Figure 9. Model SA-600 Transfer Function Synthesizer

by behaving like a four-terminal network having that function. It is designed for operation with an external signal in the same general frequency domain as the TFC, and thus may be used to simulate, or may be inserted in, almost any practical servomechanism or control-system loop. Its transfer function may then be adjusted by panel controls, term by term, to synthesize a function of up to the third order, with an unusually wide range of coefficient variation.

The Model SA-600 is mounted in a portable case, or 19" rack, (9" high, 20" wide, 9" deep) (23 cm x 51 cm x 23 cm), and weighs 29 pounds (13.2 kg).



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